TMO TECHNOLOGY DEVELOPMENT PLAN

Antenna Systems Work Area

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OBJECTIVE:
The objective of the Antenna Systems Work Area is to develop technologies associated with large aperture DSN antennas for improvement of their performance, reliability and availability while decreasing the cost of their implementation and operation.

GOALS and SIGNIFICANCE:
This work area will develop analytical tools useful in the design and analysis of RF optics and components, develop and demonstrate techniques for the accurate measurement of the antenna structure contribution to the total system stability, and develop structural, mechanical and servo control technologies that improve high frequency tracking performance. Ka-band (32-GHz) technologies to be developed by this work area include high efficiency performance of the 34-m and 70-m antennas, stable high power transmitter capability, pointing technologies enabling low loss tracking by large DSN antennas, and techniques for rapid and accurate antennas and radio sources calibration. Developing Ka-band technologies for the large ground antennas is significant because link margin improvements of 4-6 dB can then be realized, thus enabling smaller spacecrafts. Demonstrations are planned at strategic times during these developments in order to transfer the maximum possible technology to the DSN implementation.

To Compensate for the efficiency roll-off of the large antennas due to gravity, this work area is developing a deformable flat plate (DFP) for the 34-m and 70-m antennas. At Ka-band, the losses due to gravity distortions are: 2.3-dB for the 34-m R&D antenna, 2.0-dB for the 34-m HEFs, 1.0-dB for the 34-m BWGs, and 19-dB for the 70-m antennas. The goal for the DFP task is to recover all but 0.25-dB of the efficiency roll-off.

This work area is developing enabling capabilities for the Cassini Radio Science Experiment at 32-GHz. The Cassini experiment at 32- GHz represents a significant advance in radio science research, and pushes the art of antenna performance.

PRODUCTS:
The products of the Antenna Systems Work Area are:

1. Deformable Flat Plate for compensation of antenna gravity distortion at low elevation angles.
2. 800 W Ka-band Transmitter to support the initial Cassini radio science calibration at DSS 13.
3. Active Surface Amplifiers which are critical for end to end Ka-band viability.
4. High Power / Low Noise Facility: Design a facility at JPL to replace traditional Goldstone testing.
5. Raster Scan Calibration for rapid and high Precision calibration of the DSN antennas and radio sources.
6. Antenna Stability Characterization of DSS-25 to determine Allan deviation for Cassini.
7. Ceramic Waveguide of extremely low loss that reduces weight and bulk.
8. BWG IR Imaging as a tool for BWG alignment and TXR field imaging.
9. Primary Antenna CONSCAN for Ka-band.
10. Monopulse Closed loop tracking demonstration shows $<0.001^0$ pointing precision at 32 GHz.

DESCRIPTION:
The DSN is the largest and most sensitive scientific-telecommunications and radio-navigation network in the world. The large antennas are the most visible component of that system. These antennas are the focus of several disciplines including electromagnetic, mechanical, electrical and servo-control. Furthermore, the sensitivity of the receiving systems is affected by the noise performance of the antenna feeds, supports, and structure. The antenna systems also represent a considerable fraction of the total cost of a receiving station. It is therefore important that we continually improve the performance per unit cost of the antennas and increase reliability and availability of their subsystems.

The use of the Ka-band frequency allocation (32 GHz downlink, 34 GHz uplink) will allow the present 34-meter antenna systems in an arrayed configuration to provide approximately the same performance as the present 70-meter antenna provides at X-band (8.4 GHz). Many Ka-band technologies have been developed in the past several years. Examples include novel diplexing systems using either dichroics or horn input junctions that eliminate the use of lossy waveguide diplexers. For adequate performance of an antenna at a given frequency, it is required that the reflector surface (rms) accuracy be $\lambda/20$ (0.46-mm at Ka-band) and that the pointing accuracy (rms) be approximately $\lambda/(10*D)$, or a tenth of the beamwidth (1.6-mdeg. at Ka-band). The Microwave Antenna Holography System (MAHST) developed under this work area enabled the setting of the new 34-m beam waveguide (BWG) antennas to an rms surface accuracy of 0.25-mm ($\lambda/37$ at Ka-band) which has resulted in efficiencies of 57% from the F3 (BWG focus) focus at Ka-band. However, the current pointing accuracy of these large antennas at Ka-band presents a problem. Recently this work unit developed a monopulse tracking system that can be inserted into an existing system with little or no effect on the telemetry channel. By using this tracking system, the antenna pointing error--after target acquisition--will be reduced to within 1 millidegrees. This will enable tracking of spacecraft with little or no pointing loss and is planned for use in the DSN beam waveguide system that will be tracking the Cassini Ka-band radio science signal. A demonstration at DSS-13 showed that pointing error of 1.5-mdeg can be achieved with the antenna CONSCAN method. Therefore, missions requiring support at Ka-band prior to the implementation of monopulse tracking, such as DS-1, will be supported by CONSCAN. The Raster Scan task is developing instruments for deriving accurate blind pointing models and antenna efficiency versus elevation angles, which will provide the needed accuracy for antenna calibration at Ka-band.

Another area presently under investigation is Ka-band system improvements for the 70-meter antenna At present, the gain performance of the 70-meter antenna falls off dramatically as the antenna is pointed at targets either above or below the elevation angle the antenna was optimized for. Techniques for improving this situation, including deformable mirrors and array feeds, will be developed that will increase performance at a fraction of the cost of increasing the antenna size or arraying. This work area will then assess the potential Ka-band performance for future mission operations designers. For example, options for spacecraft emergency command and recovery may be made available if Ka-band is needed on the 70-m antenna

Uplink/Downlink diplexing has been developed at X-band as well as Ka-band. This work area provided a demonstration of an X-band diplexing scheme that provides dramatically improved simultaneous transmit and receive performance at very low implementation cost. The scheme used a horn input junction to diplex the uplink and downlink signals, which eliminated the standard waveguide diplexer at nearly a 3 dB increase in G/T. This system is now the baseline for the DSN X-band upgrade task for the 70-m antennas.

In order to support the Cassini system radio science system and the gravitational wave experiment, the total system stability of the antenna must be increased and the variation of the received signal must be reduced. In recent years we have studied the stability of the antenna system for a fixed pointing direction. We have not yet measured the stability of these systems while tracking a target. By determining the system stability performance of the antenna system and its tracking system-- monopulse, CONSCAN, or blind pointing--we can make better judgments as to what system best fits our needs and how best to implement them.

The aberration effects result from the apparent angular displacements produced by the actual motions of the target body and the observer which lead to different optimal uplink and downlink pointing direction

DELIVERABLES:

- Demonstrate improved 70-m performance at Ka-band using deformable mirror.
- Fabricate and test 10x10 Active Surface Amplifiers with 2-3 Watts output power.
- Measure the Stability of DSS-25 and / or DSS-26 during tracking.
- Complete all sky pointing model derived via Raster Scan technique.
- Complete the theoretical and experimental investigation of launching methods, splicing, transitions, and bends in ceramic waveguides.

- Beam aberration and point-ahead demo at DSS-13 share cost with Cassini Radio Science.
- Improve antenna servo performance by optimizing torque loops design.
- Report on G/T improvement for 34m BWG antennas.
- Complete design and lab testing to verify power handling capacity and klystron phase stability.

RESOURCE REQUIREMENTS BY WORK UNIT:

Work Unit	JPL Account #	FY'98	FY'99	FY'00	FY'01	FY'02	FY'03
Ka-Band Thrust	412-41012-333	232					
XMTR Technology	412-41014-333	230	220	200			
RF Systems	412-41015-333	200	100				
Antenna Stability	412-41016-333	275	100				
Work Area Manager	412-41021-333	75					
Total		1012	1263	1230	1230	1277	1277

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Deformable Flat Plate (DFP)	
WORK UNIT IN WHICH FUNDED: Ka-Band Thrust, 412-41012-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:

This task will develop and test a fully actuated deformable flat plate (DFP) for compensating the gravity-induced structural deformations in the 70-meter antenna.

JUSTIFICATION AND BENEFITS:

The 70-meter antenna has a significant Ka-band roll off with elevation (more than 6-dB at the lower end of the elevation range). Experiments performed at DSS-13 demonstrated that a deformable mirror could recover almost all of the gain lost to the gravity deformation. A fully controllable surface would provide the capability of nearly completely compensating for the gain loss due to gravity induced structural deformations over the entire range of elevation angles. The deformable mirror would provide the lowest cost technology for providing this capability.

APPROACH AND PLAN:

This has been a multiple year task. The initial tests at DSS-13 utilized 49 manually controllable actuators to correct the gain loss due to gravity induced distortions at a fixed elevation angle. Microwave holography was used at an elevation angle of 12.7 degrees to obtain a surface distortion map of the main reflector: 1) with an undistorted flat plate and 2) after the calculated correction had been applied to the DFP. Near-real-time holography was then used to adjust the surface to obtain the lowest RMS surface error obtainable within the short time available for the experiment. The effective RMS surface error was improved from 0.59 mm for the initial no-correction flat plate to 0.49 mm for the analytically derived correcting surface, to 0.36 mm for the holography derived DFP. This represents a gain improvement of approximately 2.0 dB at 32 GHz. Based upon the success of the experiment, a 16 actuator fully controllable deformable flat plate was fabricated. In the 49 actuator plate, the actuator locations are typically arranged in a symmetric predetermined pattern. For the fully controllable 16 actuator plate, the locations are optimized according to the required contours, thus reducing the number of required actuators while maintaining the necessary level of performance. A thorough set of mechanical tests were performed to demonstrate the robustness of the design for transfer to an operational system. The DFP was installed at DSS-13 and the holography tests repeated. The 16-actuator plate had virtually the same gain improvement as the 49 actuator plate. Efficiency measurements also confirmed the gain improvement. The DFP control system was upgraded to permit remote operations which will lower the costs of the on-going efficiency tests. The plan is to use an optimization algorithm with the DFP to derive the optimum surface as a function of elevation angle. A complete set of efficiency data over all elevation angles will then be generated.

The original plan was to refurbish the DFP (needs to fit on the 70-meter antenna and be weather protected) for the 70-meter antenna and install and test the DFP on the 70-meter antenna in the 4th quarter FY97. However, due to personnel changes and a very slow response from the model shop, the task is about 4 months behind the initially planned schedule. No additional funds above the initially requested total at completion are required. Rather, the funds need to be moved from FY97 to FY98.

DELIVERABLES:

First Qtr.	Refurbish the DFP for the 70-meter antenna.
Second Qtr.	Install and test on the 70-meter antenna.
Third Qtr.	Final report

RESOURCE REQUIREMENTS:

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)	736	100			836
Workforce (WY)	2.7	0.3			3

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Beam Aberration and Point-ahead Capability Demonstration	
WORK UNIT IN WHICH FUNDED: Ka-Band Thrust, 412-41012-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:

The purpose of this proposal is to study and perform a conceptual demonstration of the beam aberration correction and point-ahead capability for the 34m BWG antenna at Ka-band. For simultaneous transmit and receive Ka-band operation of the Cassini spacecraft, gain loss due to the beam aberration is more than 5.0 dB on the combined transmit and receive modes. This loss is due to the time lag between transmit and receive modes in deep space communication which results in the spacecraft being at two different positions. Results from this study will demonstrate and lead to the selection of antenna technologies that will minimize or eliminate this loss. This study is essential for the antenna pointing for Ka-band simultaneous operation of the Cassini radio science experiment.

JUSTIFICATION AND BENEFITS:

There are significant amplitude loss (more than 5 dB at Ka-band) and phase variations during the simultaneous transmit and receive operation while the Cassini spacecraft is traveling in deep space if the transmit and receive patterns of the ground antenna are pointing in the same direction. This is because the spacecraft is at different locations when it performs simultaneous transmit/receive communication with the ground antenna. In order to eliminate the losses, the transmit and receive patterns of the ground antenna must be able to independently point to the spacecraft. This investigation will find and verify a technique that will minimize or eliminate these losses.

APPROACH AND PLAN:

The investigation begins with the study of the impact of some antenna parameters on the beam aberration and beam pointing. Antenna parameters such as BWG reflector position and horn position will be investigated. An RF design configuration that minimizes or eliminates the beam aberration problem will be selected. The DSN BWG antennas provide two separated transmit and receive feed systems. There are several techniques that will achieve an independent beam pointing of the transmit and receive patterns. One of the techniques is by moving the transmit feed with the receive feed stationary. The transmit feed can be placed on an x-y translation platform which is preprogrammed to have an x-y motion according to a spacecraft's location. The conceptual demonstration of this technique will be performed at the R&D JPL-DSN ground antenna at Goldstone (DSS-13). Results from this feasibility demonstration will lead to the design selection and the transfer of technology to an operational DSN antenna that will be used to enhance the point-ahead capability for the Cassini radio science experiment.

DELIVERABLES:

- Antenna RF configuration that will enhance the point-ahead capability for the Cassini radio science experiment.
- The impact of antenna parameters on beam aberration and beam pointing.
- Demonstration of the Ka-band pointing with point-ahead capability for simultaneous transmit/receive operation at DSS-13.

RESOURCE REQUIREMENTS:

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)	0	180			180
Workforce (WY)	0	0.8			0.8

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Performance optimization of the az & el torque share loops of the BWG antenna	
WORK UNIT IN WHICH FUNDED: Ka-Band Thrust, 412-41012-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:

Tracking performance of the DSS13 (and other 34-meter antennas) is currently limited by both the torque share circuits (both motor-to-motor and wheel-to-wheel) and by torque bias fade circuit. These circuits are part of the antenna rate loop electronics. The response of these circuits is satisfactory for low dynamic tracks and in low wind conditions. However high dynamic tracks, like raster scan, are limited by the response of the antenna. Pointing precision is reduced as the wind increases, and is further reduced due to gusts. Increasing the gain and bandwidth of these circuits would improve the response, however the increases are limited to stability of the antenna rate loop. Optimization of these circuits through analysis and modeling would increase antenna pointing performance, reduce oscillations, and reduce gear wear.

JUSTIFICATION AND BENEFITS:

Currently antenna has non-optimal pointing performance during windy conditions and raster scans. Also, large drive torque fluctuations are observed during antenna slew (e.g. when conducting raster scans or driving to point or stow), this causes excessive gear wear and increased settling times. The improved circuitry with optimal gain, bandwidth and countertorque level will improve tracking errors (the servo will be "stiffer"). A simple way to improve pointing performance is to increase countertorque, however gear life would be significantly reduced. The optimization of the countertorque level will reduce gear wear while maintaining required pointing performance. The net result of this task will be better pointing performance in wind and reduced gear wear. It will also improve the ability of the antenna to follow high acceleration and deceleration trajectories such as Rapid Raster Scan. The new network of 34M BWG antennas has the same circuits and short comings. The results of this task will be directly applicable to the DSN. To improve the pointing for Cassini Ka-band, this implementation and performance verification of this task could be conducted at DSS 26, with a follow on implementation at DSS 25.

APPROACH AND PLAN:

1. Model and analyze the torque share circuits (both motor-to-motor and wheel-to-wheel) and torque bias fade algorithm.
2. Design optimal the circuit parameters for the required gain & bandwidth, and determine the optimal countertorque level.
3. Modify the existing rate loop torque share circuits at DSS 13, test, and iterate design as necessary.
4. Report the findings.

DELIVERABLES:

1. Expanded-bandwidth circuits and optimal contertorque levels.
2. Performance evaluation data.
3. TDA report.

RESOURCE REQUIREMENTS:

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)		52			52
Workforce (WY)		0.3			0.3
Co-funding ($K)					0
Projected Savings ($K)					0

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Cassini Radio Science 800 W Ka-Band Transmitter Engineering	
WORK UNIT IN WHICH FUNDED: Transmitter Technology, 412-41014-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:

This proposed task will provide engineering labor FY98 for the development and implementation of the Cassini Radio Science 800 W Transmitter. The Cassini Program will fund contracts, procurements, fabrication and services required for the implementation of this transmitter.

JUSTIFICATION AND BENEFITS:

This transmitter system will provide the uplink signal to be used in the Ka portion of the Cassini Radio Science experiments, including occultations and gravity wave searches, allowing data to be acquired based on the differential propagation of the X and Ka band signals. An important benefit to the DSN is that this transmitter system can also be used as the uplink source for future Ka-Band spacecraft, once the Cassini Radio Science experiments are concluded.

APPROACH AND PLAN:

The 800W Ka-Band transmitter will feature state of the art performance in terms of CW output power, and in phase stability. Development is ongoing in techniques for obtaining high phase stability at millimeter wave frequencies, and in obtaining reliable performance from the WR-28 waveguide components at near the 1kW power level. To reduce costs, the power supply and controller for this transmitter will be closely based on the DSN 4.2 kW design. Beam voltage regulation techniques developed for the HEF 20 kW X-Band transmitters will also be applied to this design.

The implementation of the transmitter will be out-sourced to MCL, Chicago with extensive JPL engineering involvement and technology transfer.

The transmitter system will be initially installed at DSS-13 to support early Cassini Radio Science systems testing. Permanent installation will be at DSS-25.

DELIVERABLES:

Antenna Systems:

- Transmitter design
- Design review

Cassini Program:

- Power amplifier assembly
- High voltage power supply
- Motor generator assembly
- Heat exchanger assembly
- Spares
- Documentation

The transmitter system will be delivered to DSS-13 December 98, and re-located to DSS-25 March 00.

RESOURCE REQUIREMENTS:

The 800W Ka Band transmitter task is funded both by Antenna Systems (engineering labor), and the Cassini Program (contracts, procurements and services). The resources below are the Antenna Systems contribution only.

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)	400	80	0	0	480
Workforce (WY)	2.5	0.5	0	0	3

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Active Surface Amplifiers	
WORK UNIT IN WHICH FUNDED: Transmitter Technology, 412-41014-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:

The purpose of this proposed task is to perform research and development of Active Surface Amplifiers, a novel method for solid-state amplification at microwave and millimeter-wave frequencies. The objective of this task is to produce a monolithic Active Surface prototype amplifier at 32 GHz and perform gain, output power, efficiency and radiation pattern measurements. A second goal of this task is to investigate spacecraft applications of this technology

JUSTIFICATION AND BENEFITS:

Conventional millimeter-wave methods for solid-state power amplification suffer from severe efficiency and output power shortcoming, due to the low specific device output power, and the large combination losses incurred in power-combining multiple devices. Conventional methods also impose stringent requirements on the phase control of individual elements, complicating amplifier packages and inducing reliability problems. The Active Surface Amplifier consist of an array of distributed amplifiers with individual input and output dipole antennas. A signal which illuminates this surface is amplified and re-radiated. This method of amplification is:

- Scalable in gain and output power by cascading surfaces, and increasing the active area.
- Scalable in frequency, subject device availability
- Low in production costs, as construction is monolithic
- Robust, with graceful degradation
- Readily integratable with beam waveguide optics and frequency selective surfaces
- Low in mass
- Higher in efficiency than a conventional amplifier with the same active device type, as this method has zero combination losses.

APPROACH AND PLAN:

In prior years, this task has developed analytical tools for the design and optimization of the amplifier unit cell, and array. The current thrust is to fabricate a prototype at 32 GHz for characterization, in collaboration with the Microdevices Laboratory of Section 386. This was planned to be completed FY 97; unfortunately, due to difficulties encountered in the HEMT photolithography, a prototype will not be available until FY98. When the prototype is completed, gain, output power , and efficiency measurements will be made. Approximately 100 mW of output power is expected from this prototype at 6 dB gain. It is planned to produce a second iteration of the prototype at the 2-4 watt output power level, beginning FY 98. A parallel effort will begin to investigate the integration of Active Surface amplifiers into a spacecraft environment in terms of packaging, cooling, shock and vibration etc.

DELIVERABLES:

1. First 32 GHz prototype Active Surface Amplifier: deliver December 97
2. Prototype measurements: March 98
3. Second iteration design: June 98
4. Second prototype: FY 99

RESOURCE REQUIREMENTS:

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)	289	150	220	200	859
Workforce (WY)	1.5	0.5	1	1	4

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Design, Analysis, and Test of New Ceramic Waveguides	
WORK UNIT IN WHICH FUNDED: RF Systems, 412-41015-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:

Through computer simulations and experiments, we have discovered that a thin ribbon with high dielectric constant low-loss material can be made into an ultra-low-loss waveguide with high power carrying capability for the Ka-band or higher. To successfully establish a new low-loss ceramic based Ka-band wave guiding system, other supporting elements, such as, transitions, bends, twists, etc., must be designed and developed. The following crucial investigations are therefore proposed:

1) Ceramic Waveguide Transitions

Waveguide transitions are required to insure low radiation loss for a dielectric waveguide structure such as the ceramic ribbon waveguide. Any radiation loss may be minimized if most of the guided power is confined within the dielectric waveguide structure. This can be accomplished by enlarging the core region of the structure. Transitions will have to be used to transform a thin, low-loss ceramic ribbon waveguide to a thicker, more tightly confined ceramic waveguide structure. How to design these transitions which would introduce minimal transition losses (due to radiation or mode conversion) will be the subject of our investigation.

2) Ceramic Waveguide Bends

To enable ceramic ribbon waveguide to turn corners, waveguide bends which will offer minimal bending losses (due to radiation or mode conversion) must be designed. Computer simulation of various curved guides with the appropriate transition sections will be carried out to determine the radiation and/or mode conversion losses.

Completion of these investigations will provide an important part of the foundation for an all ceramic low-loss ribbon waveguide system for Ka-band and higher. Computed results will be verified by experiments.

JUSTIFICATION AND BENEFITS:

These new waveguides can overcome some of the well-known drawbacks of conventional metal waveguides, striplines or microstrip lines, such as bulkiness, weight, high losses, and limited power handling capacity. The use of ceramic materials with high relative permittivity allows substantial reductions in linear cross-sectional dimensions. Simultaneously, the use of new waveguide with ribbon configuration allows waves to be guided with an attenuation factor of less than 0.1 dB/m at 30 GHz, as opposed to over 0.6 dB/m for conventional metallic guides. This provides for lighter components and more flexibility in the spacecraft antenna system design, as well as the ever-desirable lower loss and better performance at the DSN antennas.

APPROACH AND PLAN:

In this work we will investigate further the ceramic waveguide configurations and the bending and coupling losses which are significant areas of concern. Metallic to ceramic waveguide couplers or launchers will be designed to minimize radiation loss and improve vswr. Subsequently construct, analyze and measure a sample, approximately 2-meter long, ceramic guide with application in the Ka-band DSN and spacecraft antennas. concurrently, the waveguide transitions and bend will be theoretically modeled and analyzed via computer simulation by finite difference and other methods. This work follows the successful preliminary results of last year's effort. In the first year a literature search and survey was done and preliminary theoretical studies were performed. In the second year sample waveguide sections were made and tested. Based on our experimental results, as well as our computer simulations, the concept of using low loss high dielectric constant ceramic material for building practical ultra low-loss ribbon waveguides for Ka band and higher, is proven viable. This work will build on last year's effort to come up with a realistic arrangement for a ceramic waveguide application at the DSN ground station or a spacecraft antenna.

DELIVERABLES:

- **A** relatively long (a few meters) transmission demo unit using ceramic ribbon waveguides at Ka band with application to the DSN and/or spacecraft antennas.
- Theoretical analysis and computer simulation results of ceramic waveguide transitions and bends.
- A report that summarizes the theoretical findings, the demo unit design, fabrication, and test results.

SCHEDULE

RESOURCE REQUIREMENTS:

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: The Investigation on G/T Improvement for 34M BWG Antennas	
WORK UNIT IN WHICH FUNDED: RF Systems, 412-41015-333	
WORK AREA: Antenna Systems	

BRIEF TECHNICAL SUMMARY:
The objective of this proposal is to investigate the RF and mechanical elements that cause the loss in G/T of the DSN 34m BWG antennas and to propose technologies that might minimize those losses. The existing DSN 34m BWG antennas are not operating at their optimum G/T performance. The RF and mechanical components that contribute to higher noise temperature and efficiency loss will be investigated and quantified. It is estimated that the G/T improvement is about 1 dB at X-band and 3-4 dB at Ka-band. A few dB of cross-pol can also be improved. The investigation will concentrate on, but not be limited to, a better surface rms, panel gap, small cross-section struts, low loss material for BWG mirrors and the shroud, microwave and feed system components and design configuration. This study will deploy current technology and measured data obtained from the existing BWG antennas.

JUSTIFICATION AND BENEFITS:
Future TMOD operating systems require much larger communication capacity than current capacity due to the increase in the future flight projects. Building new antennas is always the last option because of the associated cost. One practical low cost option is to improve existing antennas' G/T performance and optimize time sharing among the antennas. The existing DSN 34m BWG antennas are not operating at their optimum performance. The losses are associated with several components in the RF and mechanical systems. This study will identify and quantify elements that cause the loss in G/T and propose techniques that will improve the G/T performance.

APPROACH AND PLAN:
RF and mechanical elements in the BWG antenna system (except pointing and control systems) such as RF Optics, surface rms, mirror material, shroud, gaps, subreflector support structure, gravity distortion, microwave component and the layout, etc., will be investigated. Their loss contributions will be quantified. Some redesign techniques and new technologies will be identified to reduce these losses.

DELIVERABLES:
A matrix that shows loss budget and techniques to reduce those losses.

SCHEDULE

	FY98			
	Q1	Q2	Q3	Q4
1. Study RF and mechanical elements				
2. Propose techniques to reduce losses				
3. Establish a matrix				

RESOURCE REQUIREMENTS:

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)		50			50
Workforce (WY)		0.3			0.3

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Antenna Mechanical Stability Characterization for Cassini Radio Science
WORK UNIT IN WHICH FUNDED: Antenna Stability, 412-41016-333
WORK AREA: Antenna Systems

BRIEF TECHNICAL SUMMARY:

The objective of this proposal is to characterize the frequency stability of the antenna mechanical subsystem as required for the Cassini Radio Science Experiment searching for low-frequency gravitational radiation. This includes the derivation of long (100 to 1000+ sec) and short (1 to10+sec) term Allan deviation, phase noise (1Hz to 5kHz), and amplitude variation of the detected signals. The stability of the antenna will be measured at Ku-band (12-GHz) at three different elevation angles (approx. 45, 30, and 13 degrees), utilizing geostationary satellites, and at X-band while tracking MGS. The measurements will be made utilizing similar communication signals (CW) as expected during the Cassini Radio Science experiment. From the measured data, the mechanical stability of the antenna will be inferred. From holography (amplitude and phase) boresight data, and holography raster scan data, the phase function across the antenna main beam will be studied and analyzed. From this study the antenna stability due to pointing error alone will be inferred and separated from the total antenna stability, hence deriving the stability of the antenna mechanical subsystem. Based on the information obtained, ways to improve of the antenna mechanical stability will be studied.

JUSTIFICATION AND BENEFITS:

The upcoming Cassini mission to Saturn and in particular the radio science gravitational wave experiment and radio occultation experiments demand exceptional amplitude and phase stability of the communication link carrier, thus placing a premium on issues such as pointing and antenna mechanical stability. This proposal is for the testing of the latter and assessing ways to improve the antenna mechanical stability. Measurements of the antenna stability (mechanical and pointing errors combined) during FY 97, indicated that currently, the DSS-25 antenna stability for tau=1000-sec is 2.6×10^{-15} which does not meet the Cassini radio science requirements for stability of 1.5×10^{-15} for tau=1000-sec by the year 2000.

APPROACH AND PLAN:

Geosynchronous satellites tracking: the typical “figure eight” drift of the satellite, which occurs typically in two rate “zones” will be utilized for advantage. This enable measurements while the antenna is stationary relative to the source, and while tracking the source at rates up to approximately 20-mdeg/hr. At each measurement angle (approx. 45, 30, and 13 degrees), the antenna mechanical stability will be determined for the static and dynamic (tracking) conditions. The capability to place the subreflector in “lock” or “track” mode, as well as z-axis movement, will add additional data for further understanding of the trade-off between G/T and pointing error on antenna stability during the experiment. In the initial stages of this work the stability of the MAHST was measured and characterized in the laboratory and on the roof of building 238. Data acquisition software for computing Allan deviation and phase noise and display the raw data and computed values in real time, as well as software to track the geostationary satellite were developed during FY 97. Also during FY97, all the hardware necessary to track MGS (or any other spacecraft carrying X-band transponder with a CW beacon) at X-band was procured. This includes multipliers for the receiver to enable tracking at the DSN X-band frequency band, and a servo system integrated with the 2.8-m diameter reference antenna to enable slaving it to the antenna under test. Also during FY97, computational methodology was developed to enable separation of the antenna mechanical stability from the stability due to pointing error alone. Field measurements at Goldstone DSS-25 and DSS-26 will be conducted utilizing the instruments developed during FY 97. A 2.8-meter reference antenna, located within a diameter distance from the phase center of the antenna under test is used as a phase reference and an optional PLL channel to the dual channel coherent receiver.

DELIVERABLES:

Knowledge of the DSS-25 antenna stability as required for supporting the Cassini radio science mission and possible assessment for improvement of the antenna stability.

Publications FY97:

1. D. J. Rochblatt, P. H. Richter, and T. Y. Otoshi, “A Microwave Performance Calibration System for NASA’s Deep Space Network Antennas, Part 2: Holography, Alignment, and Frequency Stability”,Proceeding 10th Int. Conf. on Antennas and Propagation pp. 1.150-1.155, vol. 1, 14-17 April 1997.

2. P. Gorham and D.J. Rochblatt, “Effect of pointing Errors on Phase Stability and Interferometric Delay”, JPL IOM 335.1-97-023, August 11, 1997

RESOURCE REQUIREMENTS:

	Prior Year(s)	**FY98**	**FY99**	**FY00**	**Total at Completion**
Funding ($K)	230	150	50		450
Workforce (WY)	1.2	1.0	0.3		2.5

TMO TECHNOLOGY TASK DESCRIPTION

TITLE: Development of Precision Antenna and Source Calibration via Raster Scan at DSS-13
WORK UNIT IN WHICH FUNDED: Antenna Stability, 412-41016-333
WORK AREA: Antenna Systems

BRIEF TECHNICAL SUMMARY:

The objective of this proposal is to develop and demonstrate at DSS-13 the precision antenna and source calibration technique utilizing raster scan for determining antenna efficiency, pointing models, pointing errors, system noise temperature, subreflector position, and residual aberrations. This technique offers an order of magnitude reduction in measurement errors relative to current techniques (i.e. AutoBore, Fields System) used in the DSN and elsewhere, and therefore it is critical especially for Ka-band. Upon successful demonstration of the technology at DSS-13, further proposals for development of the technology for the DSN will follow. Based on demonstrations achieved thus far at DSS-13, infusion is already under way into the blind pointing task for Cassini at DSS-25.

To summarize the objective and rational of the technique:

A. Removes a major source of error in determining the antenna efficiency by eliminating the need for independently derived source-size correction factors.

B. In the derivation for optimum integration time during the raster scan measurements, the actual spectrum of the total power radiometer test package is taken into account as well as the troposphere turbulence effects and the front-end thermal noise. Other techniques (i.e. AutoBore and others) assumes only front-end thermal noise, which is satisfactory only up to X-band.

C. Provides a direct comparison of the flux density of one source with that of another, thus enabling the accurate calibration of sources.

D. Highly accurate, repeatable, and fully automated system, will provide reduction in cost and improve the reliability of the antenna performance.

JUSTIFICATION AND BENEFITS:

For an adequate performance of an antenna at a given frequency, it is required that the pointing errors will be less than a tenth of the antenna half power beamwidth (HPBW). The HPBW of the DSN 34-m antennas at Ka-band is 16-mdeg thereby requiring a 1.6-mdeg pointing error (0.11-dB). The current blind pointing of the DSN 34-m BWG antennas is between 5 and 9 mdeg. The objective of this proposal is to develop techniques for antenna measurements that will enable blind pointing model accuracy's of 0.15-1.5 mdeg and which are limited by antenna mechanical performance and not by the measurement system. The improvement in blind pointing model is especially important for the Cassini radio science gravitational wave and radio occultation experiment at Ka-band. This work already infused into the blind pointing task for Cassini at DSS-25. Other benefits include: improved noise temperature measurement precision to 0.03K down from 0.14K for other techniques, and improved antenna efficiency versus elevation angle measurement precision to 1% down from 5-10%.

APPROACH AND PLAN:

The raster scan technique for DSS-13 will be developed as a stand alone test equipment utilizing the MAHST computers and TPR test packages operating from the antenna pedestal room. Station equipment capabilities will be enhanced and / or upgraded with the goal of station personnel to be able to conduct raster scan measurements. Also capability to raster scan against the Sun will be developed.

DELIVERABLES:

A raster scan technique and system for accurate determination of antenna pointing models, efficiency, and source calibration. The goal is to transfer the technology to DSS-13 operation personnel. The new HP power meter HP E4418A which has improved specifications and ability to sample at 200/sec will be integrated into the raster scan systems (stand alone and DSS-13 equipment's).

Publications FY97:

1. P. H. Richter and D. J. Rochblatt, "A Microwave Performance Calibration System for NASA's Deep Space Network Antennas, Part 1: Assessment of Antenna Gain and Pointing, and Calibration of Radio Sources", Proceeding 10th Int. Conf. on Antennas and Propagation pp. 1.142-1.149, vol. 1, 14-17 April 1997.

RESOURCE REQUIREMENTS:

	Prior Year(s)	FY98	FY99	FY00	Total at Completion
Funding ($K)	86	150	50		261
Workforce (WY)	0.5	1.0	0.3		1.6